

A Summary of the Third Persh Conference: Strategic Issues in Materials for National Defense

by Dana M. Granville

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14. ABSTRACT The third in a series of conferences named after Jerome Persh was held 26–28 October 2010 in Washington, DC. “Workforce Development – Meeting Material Science and Engineering Needs for the 21 st Century” gathered delegates from industry, academia, the U.S. Department of Defense (DOD), and other government agencies to examine how these sectors could shape educational opportunities in workforce development to meet DOD’s future needs. The conference was considered timely because international competitiveness and the perception that U.S. influence in science and technology is decreasing. There appears to be a need to excite the future DOD materials and processes workforce. It is apparent that by starting materials education earlier, educating the general public of such education’s value, and engaging all stakeholders early, including teachers, there is an opportunity to reverse this trend.					
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Foreword

The Defense Science and Technology Reliance 21

The Defense Science and Technology Reliance 21 Materials and Processes (M&P) Community of Interest (COI) provides materials technologies and processes, related research and technology products, and the scientific and engineering expertise needed to maintain and enhance U.S. defense capability. Its goals are to strengthen science and technology (S&T) planning by improving the integration of S&T investments with a U.S. Department of Defense (DOD)-wide strategic view that incorporates all the service/agency plans, and by enhancing coordination between S&T communities within the DOD. Its activities include assessing the technical health of DOD M&P investment areas, identifying technology trends and emerging S&T opportunities, and facilitating collaboration among stakeholders to optimize cross-service cooperation and opportunities.

The Defense Science and Technology Reliance 21 M&P COI principal members are:

- Mr. Robert Rapson, U.S. Air Force Principal and Chair
- Dr. Lewis Slotter, Office of the U.S. Secretary of Defense (OSD) Principal
- Dr. Julie Christodoulou, U.S. Navy Principal
- Mr. Michael Maher, U.S. Army Principal
- Dr. Leo Christodoulou, U.S. Defense Advanced Research Projects Agency (DARPA) Principal
- Dr. Timothy Leong, U.S. Defense Threat Reduction Agency (DTRA) Principal
- Dr. Douglas Schaefer, U.S. Missile Defense Agency (MDA) Principal

The Committee on the Third Persh Conference, “Workforce Development – Meeting Material & Science Engineering Needs for the 21st Century,” included:

- Mr. Dana Granville, U.S. Army Research Laboratory (ARL), Chair
- Dr. Tia Benson Tolle, U.S. Air Force Research Laboratory (AFRL)
- Mr. Warren Johnson, Universal Technology Corporation (UTC)
- Ms. Cathy Santore, Zimmerman Associates, Inc.

Preface

The Persh Conference Construct

The Persh Conference construct was developed as a new forum that would include a diverse audience for in-depth investigation and discussion of issues of common interest and relevance to the U.S. Department of Defense (DOD) materials and processes (M&P) community. The conference was initiated by the Defense Science and Technology Reliance 21 M&P Panel, which recognized that direct communication among the stakeholders is a valuable way to identify common issues to be addressed or further assessed.

In a setting that does not exist in traditional forums, the Persh Conferences provide a means of rapidly assessing the issues the M&P community faces. To encourage an open and frank exchange of ideas and to stimulate a broader discussion of key issues, strategic investment, and policy options, Persh Conference attendance is by invitation only, and there are no published proceedings. Diverse stakeholders with perspectives that range from technology to policy and from research to application are brought together to focus on a single topic. The conference format includes talks that provide context and interactive panel discussions that explore and probe issues and opportunities. The results of each Persh Conference are analyzed, and assessments and/or recommendations are developed and submitted to the DOD and shared with the participants. Each conference addresses a distinct materials-related topic of strategic importance, ranging from thermal management materials to data mining, and from standardization to educational collaborations. The forum is unique because it provides a holistic look at a topical subject in a national security context and enables the identification of areas in which the M&P community should focus its research efforts and energy.

The conference is named for Jerome (Jerry) Persh, in recognition of his leadership in the defense materials community. Mr. Persh was the inspirational leader of the DOD materials development community for nearly four decades. His tenure as the staff specialist for materials and structures in the Office of the Director of Defense, Research and Engineering (Advanced Technology) from 1967 to 1996 is noteworthy. In that influential position, Mr. Persh provided outstanding policy assistance and program guidance to the military departments and defense agencies. Many important contributions to the development of key DOD materials technologies, including composites and laser protection materials, were the result of his efforts. Mr. Persh served as the DOD representative on many critical government/industry committees, including the National Academy of Sciences, the National Materials Advisory Board, the DOD information analysis centers, and The Technical Cooperation Program. He was the recipient of numerous government and industry awards. Mr. Persh's counsel was highly valued by many people, and he remained active in an advisory capacity until his passing in November 2008.

Executive Summary

The Third Persh Conference was held 26–28 October 2010 in Washington, DC. The conference, “Workforce Development – Meeting Material Science and Engineering Needs for the 21st Century,” provided the opportunity to gather representatives of key disciplines from industry, academia, U.S. Department of Defense (DOD), and other government agencies to examine how industry and DOD may quickly exploit material opportunities that are identified. Some of the more important key issues/questions that were explored during the conference included:

- Obtaining an adequate balance of current core undergraduate curricula for materials science, engineering, and material specialization for the 21st century workforce.
- Effective linkages among institutional faculty, departments, and other colleges/universities to ensure sufficient depth and breadth of subject matter.
- Young professional perspectives.
- The role of community colleges and web-based learning for maturing the local materials manufacturing workforce.
- The role of the DOD and national laboratory system in material science and engineering.
- The role of professional material societies in guidance, mentoring, and maintaining the health of our workforce.
- Policy discussions on how government and industry can better engage education.

The subject of the conference was considered to be very timely because of international competitiveness and the perception that U.S. influence in science and technology is decreasing. There is a need to excite our future DOD materials and processes workforce by starting materials education earlier, educating the general public of its value, and engaging all stakeholders early, including teachers. There is also a need to understand the motivation of the future workforce (the millennium generation) to effectively reach, motivate, employ, and retain them.

The conference consisted of three days of panel sessions that followed the keynote speaker, Dr. Lyle Schwartz, who presented “Materials Education: STEM [science, technology, engineering, and mathematics] Gateway and Integrator, University and Society Roles.” An overview of the conference follows:

- Day 1 featured an academic panel session on “Accreditation, Balance, and Curricula for the 21st Century.”

- Day 2 comprised six panel sessions, including academic panels on “Unique Collaborations in Academia” and “Role and Activities in Community Colleges,” and panels on “Young Professional Perspectives,” “Industry Needs and Activities in Developing Workforce of the Future,” “Technical Society Role in Workforce Development,” and “DOD, NASA, and Government Laboratory’s Role and Activities.”
- Day 3 comprised two panel sessions, including policy panels on “How Does the US Government Better Engage Education” and “DOD Adapting Existing Personnel Policy to New Needs.”

The conference developed the following observations:

- Undergraduate materials science and engineering (MS&E) education is dynamic in content, needs, students, and delivery methods. Curricula are updated regularly to take into account changing emphasis. MS&E courses are taught in several engineering departments.
- Teaching concepts should be applied to engage as well as prepare undergraduates for the job environment early, and include interdisciplinary training, product development focus, applied learning, and relevance.
- Teaching fundamentals should focus on using more relevant, modern, and exciting materials to engage students.
- Government investment in technology areas is a significant factor in research programs and graduate degree focus. The DOD has seen broad trends in the classification and recruitment of scientists and engineers (S&Es) and can steer interest in specialized technologies by awarding grants.
- While the current DOD workforce has a gap in distribution of age/generations due to the hiring freeze in the 1990s, no DOD retirement crisis is foreseen in the next 10 years.
- Government/industry and government/academia relationships provide a valued service in workforce development. High-value public-private partnerships align incentives and interests via collaboration initiatives, but most today are regional or local.
- The DOD has seen broad trends in the classification and recruitment of S&Es. Industry focuses on depth while government is more oriented toward breadth and flexibility.

A number of significant questions were raised during the conference. They included concerns about the balance between imagination, creativity, innovation, and critical thinking, on one hand, and on the other, the specific knowledge that is needed; there seems to be no agreement on the appropriate balance. Another question raised was how we can push “real world” teaming, interdisciplinary, and discovery skills lower (i.e., earlier) in the educational process. In addition, a whole series of challenges were defined, many of which were focused on what the DOD materials and processes community can do to ensure future workforce availability.

1. Introduction

This Third Persh Conference program, “Workforce Development – Meeting Material Science and Engineering Needs for the 21st Century,” was selected because our current U.S. Department of Defense (DOD) materials and processes (M&P) engineering community is facing an increased demand for defense materials that exhibit multiple functionalities. These materials combine the best attributes of performance and protection for the soldier at the lowest possible weight. The issue of ensuring our future workforce is not well bounded. While the need for this future workforce is well understood, it is not known whether we will have the quality and quantity of trained scientists and engineers (S&Es) in the materials science and engineering (MS&E) fields to meet the need. The conference was designed to address diverse, full-spectrum perspectives, including those from academic (colleges, universities, and community colleges; grades K–12 science, technology, engineering and mathematics [STEM]), industry, and government laboratories, and professional technical societies. It also sought to include new horizons and technology, young professionals, policy directives from academic and OSD perspectives, and workforce studies and programs within the DOD.

The conference focused on two goals:

1. Identify the challenge in our education system and workforce to meet the need to develop, apply, and transfer interdisciplinary, knowledge-based, property/structure/processing /performance tools that will successfully bridge material science and engineering curricula to product specialization.
2. Examine how to better attract, train, and transition MS&E personnel with the skills to more quickly identify, understand, and exploit new materials opportunities.

Key issues and questions that were explored included obtaining the right balance of current core undergraduate curricula for materials science, engineering, and material specialization for the 21st century workforce. It also included: developing effective linkages among faculty departments at colleges and universities to ensure sufficient depth and breadth of the subject matter; young professional perspectives; the role of community colleges and Web-based learning for maturing the local materials manufacturing workforce; and the role of the DOD and government laboratory system in MS&E. In addition, consideration was given to the role of professional materials societies in providing guidance, mentoring, and health maintenance for our workforce, and policy discussions for government and industry to better engage education.

The major themes of the conference were timely considering the extent of international competitiveness and the perception that the U.S. share of new science and technology (S&T) is decreasing. Additional attention was given to the imperatives of the DOD Director of Defense Research and Engineering (DDR&E), including the need to develop a world-class STEM and

prepare for an uncertain future. There is a need to excite our future DOD M&P workforce, including getting an early start, educating the general public, and engaging all stakeholders, including teachers. We need to motivate the future workforce (the millennium generation) to effectively reach, employ, and retain them. There are many outreach projects spanning community colleges, technical societies, the National Air and Space Administration, DOD, and others.

The conference was organized into the following panels:

- “Accreditation, Balance, Curricula for the 21st Century” (academic)
 - “Unique Collaborations in Academia” (academic)
 - “Role and Activities in Community Colleges” (academic)
 - “Young Professional Perspectives”
 - “Industry Needs and Activities in Developing M&P Workforce of the Future”
 - “Technical Society Role in Workforce Development”
 - “DOD, NASA, and Government Laboratories Roles and Activities”
 - “How Does the U.S. Government Better Engage Education?” (policy)
 - “DOD Adapting Existing Personnel Policy to New Needs” (policy)
-

2. Background

The M&P field is relatively small. Today’s MS&E education system has several stressors that are impacting the development of the future workforce. The issue of ensuring that we have the quantity and quality needed for the future workforce has not been well investigated.

The national rallying challenge is: How do we engage the future workforce? In the case of the STEM and MS&E graduates, there was a general feeling that we are losing ground compared with other academic fields and other countries. The role of innovation in economic competitiveness and national defense is very important. However, we face a challenge in getting a voice, since we have no MW&E “Sputnik” to rally around. With the grand challenges humankind faces today, is there an opportunity to generate passion in the next generation? Could the next generation’s social responsibility couple with energy and ecology challenges to generate excitement? Who poses such a challenge today? Is it the U.S. president, as John F. Kennedy did in the 1960s race to the moon? Some other person? A community? Who? Does the DOD have an opportunity to put forth a sustained, consistent message? What are our

individual and collective responsibilities as S&Es to inspire, be role models, and work with the education enterprise?

There are many individual (though noncoordinated) programs available to address MS&E workforce development. They include those of technical societies, industry, personal training programs, DOD, educational capstone projects, competitions, Army outreach programs, and many activities ready to be employed. Diversity and inclusiveness are aspects of some. There are also conflicting viewpoints and data on whether we have or will have a shortage of engineers.

To set the stage for the conference, Dr. Lyle Schwartz presented a keynote address on “Materials Education: STEM Gateway and Integrator, University and Society Roles.” His presentation included four topics:

- Topic 1 - Attracting students to science and engineering using materials
- Topic 2 - The ASM Materials Education Foundation/ASM International camps program
- Topic 3 - Undergraduate materials science and engineering
- Topic 4 - Professional society roles

2.1 Topic 1 - Attracting Students to Science and Engineering Using Materials

The focus should be on exciting young minds, providing hands-on, inquiry-based learning linking science to engineering application. Dr. Schwartz’s basic principles were to (1) grab students early in life with something that excites their native intellectual inquisitiveness, (2) provide excellent teachers who can stimulate and encourage them as they mature, (3) lead them toward career opportunities that will be rewarding to them and to society, and (4) use materials—“the stuff that things are made of”—as the gateway to the sciences and engineering.

Using materials science as a gateway, we should provide informal approaches for the public and K–6 children and take advantage of museums, the internet, TV, and the theater. Also, we should use more formal approaches for middle school children, including the internet, demonstrations and modules, and professional development. Use formal approaches for high school children, including summer camps, professional development, and modules and courses. There are many funding sources and many providers available with mostly local interactions.

Dr. Schwartz then focused on several programs with a national reach. One was called “RPI – Molecularium,” which is a “nanotoon” prepared by Rensselaer Polytechnic Institute. A cartoon feature based on some elementary principles of nanotechnology, it has been shown in more than 17 museums and planetariums across America and will be available in an IMAX version at “theaters near you.”

A second program is Museum Shows, prepared by Pennsylvania State University. With the Franklin Institute, the university produced two 60-min, cart-based, interactive demonstration kits. The first, “Materials Matter,” explores the “micro” mechanisms behind the unusual and

surprising “macro” behavior of materials such as aerogels, shape-memory alloys, polymers, electronic ink, and zeolites. The second demonstration kit, “Zoom in on Life,” investigates how the nanometer-sized parts of our body function to make life possible. Both shows have been distributed to ~20 science museums nationwide.

Dr. Schwartz reported that a number of other programs also are available. Cornell University has the NanoScale science and technology facility, which has developed a web page called Nanooze for kids to learn about the latest exciting developments in science and technology. The site contains interesting articles, geared to an appropriate age level, about recent discoveries and what they might mean for the future. There is also the Materials Research Society (MRS) “Strange Matter” museum exhibit and website, which have information concerning the secrets of everyday things. A program entitled “MRS-NOVA” discusses materials from the Stone Age, Bronze Age, and Iron Age up to more recent periods dominated by plastics and silicon, and demonstrates that materials have defined the progression of humankind. There is also a four-part special series on the Public Broadcasting System entitled “Making Stuff,” which explores the materials that will shape our future. It premiered in February 2011 and attracted millions of viewers. ASM International developed the “City of Materials,” an interactive game for students. ASM offers try-it-yourself experiments that can be performed in the classroom or at home. It has links to other sites highlighting games, videos, and career information. There are also podcasts on materials and links to award-winning ASM Materials Education Foundation programs and scholarships.

Northwestern University has developed the Materials World Modules, which are one- to three-week supplements to high school science courses that cover a series of subjects, including biodegradable materials, biosensors, ceramics, composites, concrete, environmental catalysis, food packaging, nanotechnology, polymers, smart sensors, and sports materials. The program includes the “Hook,” which is a compelling introductory activity that inspires inquiry. It contains four to five hands-on exploratory activities based on materials science and nanoscience concepts. There is also the Design Project, in which students apply their learning to create a functional prototype product.

2.2 Topic 2 – The ASM Foundation Camps Program

Dr. Schwartz discussed the Materials Camps offered by the ASM Materials Education Foundation (ASM MEF), the mission of which is “To excite young people in materials, science, and engineering careers.” The audiences targeted by the camps are high school students. Since the year 2000, ~5000 students have attended at 141 locations. In 2010, ~800 students attended at 24 locations. High school teachers also participated. Since 2002, ~2400 teachers participated at 98 locations. In 2010, about 800 teachers attended at 28 locations, receiving standardized content from trained master teacher instructors. Why focus on students? It’s fairly obvious that these students wanted to be reached, inspired, and encouraged to pursue careers in this field. However, even with the tremendous effort, only about 800 high school students are reached each

year. The question becomes, “How can a million students be reached?” In his presentation, Dr. Schwartz asked, “Why Teachers?” Inspiration is one reason. Many students become inspired to seek science and engineering careers through practical hands-on engagement and frequent reinforcement. Another is mentorship. High school teachers exert significant career choice influence and are gatekeepers who can remove perceived academic roadblocks. Leverage is a third reason. Reaching one teacher enables outreach to many hundreds of young people over many years. With this effort, hundreds of teachers are being reached each year. The goals of the teachers’ Materials Camp are to provide informative and entertaining classroom experiences for high school STEM teachers, stimulate interest in materials science, provide access to teaching kits and demonstrations, and encourage the use of content in existing courses or in newly developed materials science courses. This is truly professional development for STEM teachers.

The Materials Camp for Teachers program was developed at the Pacific Northwest National Laboratory in Richland, Washington, and is a product of the U.S. Department of Energy and Battelle Energy Alliance, LLC. In Washington state, high school teachers were trained and high school materials courses offered in collaboration with the University of Washington, with funding provided by the National Science Foundation (NSF). The ASM Foundation camps were built on the Washington state experiences. There were 30 high school STEM teachers at each camp, with no charge for attendees, who also received college entrance credits. The camps cost ASM MEF and its partners \$15,000 for a commuter format and \$45,000 for a residential format. Camp content included:

- Introduction to materials
- Metals
- Ceramics
- Polymers
- Composites

Teacher camps definitely have an impact in high schools. There was uniform praise by surveyed participants for the content and teaching methodology. Some 86% of the 513 survey respondents in 2008–2009 report they have used one or more materials science technology (MST) demonstrations in their classrooms. Many teachers return for a second stimulus and advanced instruction. There is no question that students are being reached through their teachers. Some “pioneering” teachers have developed and are teaching full materials courses:

- Washington State – Materials Technology
- Albuquerque, NM – Materials Chemistry
- Columbus, OH – Materials Science/Engineering
- Data show that there are 130 “pioneer” teachers from 14 states.

On-line program content and support network is now available. The variety of technology/science/engineering options offers a path for STEM integration. There is a planned expansion to 48 locations by 2015.

2.3 Topic 3 - Undergraduate Materials and Science Education

Dr. Schwartz pointed out that materials education at the bachelors of science level is evolving under an array of self-generated and external stresses. Undergraduate materials education occurs primarily in engineering schools with departments dedicated to both science and engineering, and is increasingly broader in technical scope. Specialized education in MSE cannot be expected to occur in the manner that it once was.

Over the past 50 years, metallurgy and ceramics merged and transitioned to materials science. Stimulated by extensive and diverse research support, graduate programs grew and thrived. The number of U.S. MS&E departments increased to more than 100 and then began to decrease as small departments merged with other disciplines or were closed. The current undergraduate degree status is as follows:

- Total number of departments accredited by the Accreditation Board for Engineering and Technology, Inc. (ABET): 70
- Number of titled MSE degree programs: 40
- Number of degree titles that include Materials: 57
 - Degree title includes Metallurgy: 7
 - Degree title includes Ceramics or Glass: 4

Currently, there are only 46 independent materials undergraduate departments. Materials degrees are also offered by 30 embedded departments—merged departments, e.g., Mechanical Engineering and Materials, and other engineering programs that have absorbed smaller materials programs. Some remaining small departments may be threatened with being absorbed into larger engineering departments. What is the future for embedded departments? Will materials programs disappear, or will these be the only homes for materials engineering?

Faculty size and undergraduate population are both growing in the top departments. Overall, enrollments are growing, further increasing student body size in larger departments. Undergraduate degrees remain strong even as the number of departments decreases.

Data from the 2007 *US News and World Report* survey of undergraduate departments indicate that the top 15 undergraduate MSE departments are:

- Carnegie Mellon University

- Cornell University
- University of Florida (UF)
- University of Illinois at Urbana-Champaign
- Georgia Institute of Technology (GT)
- University of Michigan
- Massachusetts Institute of Technology (MIT)
- Northwestern University
- Ohio State University
- University of Pennsylvania
- Pennsylvania State University
- Purdue University
- Stanford University
- University of Wisconsin
- University of California-Berkeley

The average department has 32 faculty, with MIT and GT quite large, but most in the mid-20s. Among the top 15, the average department has faculty with Ph.D. backgrounds, including 38% MSE, 8% Metallurgy, 5% Polymer, and 2% Ceramics, and, by contrast, 30% Physics and Chemistry. This healthy research environment makes it increasingly difficult to find engineering faculty background for in-depth undergraduate *engineering* specialization. All engineering curricula remain under pressure to move “cutting edge” material into undergraduate courses and keep course loads the same as other disciplines. There is also pressure to expand entrepreneurial, financial, and international experiences. In addition, there is increased breadth and decreased depth. For example, there are “vertical” courses, or those covering one material or technique in great depth, and “horizontal” courses that touch on general phenomena, many materials, or many experimental techniques. At UF, the MSE undergraduate program has changed from 23 horizontal and 29 vertical courses in 2002 to 34 horizontal and 14 vertical in 2008.

There are other issues. For example, if specialization (depth) isn’t taught at the undergraduate level, when will it be taught? The National Academy of Engineering “Engineer in 2020: Visions of Engineering in the New Century” program defines challenges for engineering education, concluding that the master’s degree will be the “professional” degree. The master’s degree and/or continuing education is the path for specialized technical development in materials engineering. Is this issue being given enough attention? Another issue for engineering schools is, “What do engineers learn?” At some schools, materials courses are taught by MSE, while at

others, they are taught by each engineering department. Also, materials research is being performed by faculty in departments not titled “Materials.” Many universities and colleges have *no* materials department. Therefore, what is the content and character of materials education in the other engineering fields?

2.4 Topic 4 - Professional Society Roles

Engineering professional societies should provide: technical information exchange/standards, networking, professional recognition, and support for education of the next generation. The materials field is weakened by its disaggregated society system. This is most apparent in education. The current status of MS&E community needs:

- Support accreditation.
- Enable society participation.
- Assist curriculum development.
- Provide a home and support for data collection and sharing.
- Organize workforce placement.
- Provide continuing education.

Dr. Schwartz pointed out that professional society cooperation is finally happening. There are technical meetings on materials science and technology and student chapters of the various materials societies. There is ABET oversight from the Minerals, Metals & Materials Society, American Ceramic Society, and MRS. To build on these successes, the Undergraduate Education Coordinating Committee was formed in 2009.

According to Dr. Schwartz, there are many forms of outreach in place, bringing students to materials departments in increasing numbers. Undergraduate materials education has become quite broad and lacks depth of specialization. However, professional societies and universities have begun to collaborate on issues of common concern in materials education.

3. Education

3.1 Undergraduate MS&E Education

Engineering education necessarily evolves to ensure that a graduating engineer is adequately prepared to address most of the common problems that he/she will meet in practice. Recent studies by the National Academy of Sciences identify new instructional methodologies and offer new means for assessing engineering graduates' academic development.

Content delivery methods are changing to match today's media and formats, including the content, needs, students, and delivery methods. There is a growing role for the dramatic increase in computational power; the computational paradigm for MS&E is upon us. The significance of integrated computational materials engineering is increasing dramatically, as well as the need for a skilled workforce in this area.

Changing workforce needs are driving all engineering departments to add content on design, business, communication, and other nontechnical topics, while the technical landscape is simultaneously expanding in each of these fields. In the four-year undergraduate curriculum, this new content is introduced at the expense of more traditional subjects, leading many engineering leaders to suggest that the professional engineering degree and certification be moved to the master's level. While workforce needs continue in many traditional areas, faculty expertise evolves, driven largely by research opportunities that trend toward new, cutting-edge topics.

Curricula are proactively updated periodically to take into account changing content. Some examples given during the presentations included those changes occurring at Purdue University and the University of Washington. Another example presented was about creating a completely new department at the Rochester Institute of Technology, where teaching concepts within today's context are integrated with a focus on materials engineering needs supporting businesses in the local economy. Although MS&E is taught primarily in engineering departments, it is also now being taught in various other departments, which leads to a different educational focus.

Many engineering schools include departments specifically dedicated to the study of materials. The education provided by a degree in materials prepares graduates for career options that include either industrial practice or advanced study leading to research. Traditional materials topics such as metals, ceramics, polymers, and electronic materials have now expanded to include nanomaterials and biomaterials. As research areas broaden, some topics move from graduate to undergraduate curricula, displacing traditional subject matter and ensuring an undergraduate experience that is typically quite broad, but with little depth in any particular materials subject. At the same time, computational and communication tools have become

available that are creating a new materials-design paradigm, opening new avenues for research and application but requiring new educational experiences as well.

Course requirements change with time. Mathematics requirements have not changed much since World War II, yet variability in engineering fundamentals has definitely been seen over time. There are very diverse opinions on whether the United States graduates a sufficient quantity of STEM graduates, and graduates of sufficient quality.

3.2 Stresses on Academia/Curricula

There are many stresses on academia and the curricula. MS&E departments are often embedded within other departments. There are only 46 undergraduate materials departments in the United States. Others have been merged with, or absorbed by, other departments in the universities. Therefore, achieving a balance of core vs. cutting edge courses is difficult, resulting in tradeoffs between breadth and depth. New research directions often are introduced at the graduate level as they become viable, then they become electives, and are then integrated within the core. The workforce might require both breadth and depth—a mix of specialists/generalists on one team.

Limited local faculty expertise and limited curricular flexibility suggest the need for alternate approaches in education. In response, the way in which engineers are educated is changing. For example, there has been increased attention to continuing-education opportunities for practicing engineers, addressing the need for content beyond that available in the four-year program. Additionally, advances in communications technology have opened up opportunities for distance learning, which could enable more depth in topical coverage for students in departments without local faculty expertise.

There are other considerations as well. Fitting the required coursework into a four-year degree is already difficult. However, providing work experience in addition is also highly valued. It provides many benefits to education in the long run, but can add a significant challenge to fitting everything into a four-year degree. So how do we develop key attributes identified by National Research Council reports, industry, and new graduates that are qualities and attributes necessary for success vs. course content, for example, to produce an adaptable workforce? There are many stakeholders in curricula development that focus on this problem. Some departments even use advisory committees to get input on how to reach an acceptable balance between curricula content and providing some amount of work experience.

4. Government Role

4.1 Government Role in Workforce Development

The role that the government plays in workforce development is a very significant factor. Government investment in technology areas is very important in research programs and in the focus of graduate degrees. Funding can definitely shift the focus from one aspect to another. An example is the erosion of basic research areas as academics choose “hot areas” to compete for funding opportunities that are not in the basic arena.

Also, many individuals benefit from DOD activities during their development. Basic research (6.1 funding) sponsorship of STEM/graduate education is very significant, touching many graduate students. An estimated \$2 billion per year goes into this area. In addition, individuals spending time in DOD laboratories during their education benefit significantly through the hands-on experience they receive. According to Institute for Defense Analysis (IDA) studies on potential scenarios, the DOD can steer interest in specialized technologies by awarding grants.

The government role in workforce development impacts many. DOD is one of the largest employers of scientists and engineers and the largest federal scientist and engineer employer. Some 45% of all federal scientists and engineers in 2005 were employed by DOD—some 100,000 scientists and engineers. DOD is also the largest supporter of graduate students. As such, it is a key partner with academia in the development of students to solve problems that benefit U.S. national security.

The current DOD workforce has a gap in the distribution of age/generations due to the hiring freeze that occurred in the 1990s. Underrepresented groups in engineering are typically even more underrepresented within the current DOD workforce. However, no immediate retirement crisis is foreseen in the next 10 years for DOD (based upon an IDA study). About 20% leave DOD every five years, and retention rates are lower for younger scientists. A significant portion of older scientists and engineers will retire in the next five years, and most will have left by 2020. Scientists and engineers usually retire well after they are eligible, mostly a function of the state of the economy and other external factors.

4.2 Government/Industry/Academia Relationships

Government-industry and government-academia relationships provide a valued service in workforce development. Centers of excellence offer a high value for DOD workforce development on several levels. They can capture and build upon the available knowledge base. They can also train students and the future workforce quickly, so early on these students can see the value in careers with the DOD. In addition, NSF data show a direct benefit to individuals doing research in a center of excellence type of environment.

Partnerships help develop mature new employees. Several different models exist for DOD-academia collaborations. They articulate the benefits to university, industry, and government. The question is: Is a new era of government-university partnership already here or is one needed? Bringing together the complementary strengths, characteristics, and abilities among government, industry, and academia benefit all parties. In addition, these partnerships spawn regional economic growth.

4.3 Government Partnering

There are challenges in government partnering, however. The DOD may not be set up for effective partnerships with universities. There are DOD infrastructure limitations, including space and information technology(IT)/security barriers. The perception of DOD having an “environment of dinosaurs” is a risk when partnerships are handicapped by the IT/security barriers. Also, there is no apparent official “credit” for outreach efforts made by DOD personnel. Further, the duration of most funded and/or structured partnerships/collaborations is too short for the development of effective relationships.

The materials and processes community is not a large one. Therefore, the DOD may need to rely upon alliances and relationships to make necessary connections and to identify the future workforce.

There exist opportunities for improved transparency of, and accessibility to, DOD opportunities that could greatly enhance individual and organizational relationships. For example, there appears to be no centralized site to look at all of the summer internships across multiple DOD laboratories. Therefore, could partnering with technical societies help serve to communicate and knit together the community? Workforce development is a shared concern across multiple disciplines, cities, and states. Could there be existing activities that the DOD can plug into?

5. Society Perception of MS&E

Society’s views of the characteristics of materials scientists and engineers indicate confusion and a general lack of knowledge regarding what engineers and scientists do for society. One delegate to the conference reported that this was concluded from a survey performed by the NSF. Additionally, there is a lack of perceived value for the contributions engineers make on the part of individuals, organizations, and, in fact, the entire nation. Society lacks a common understanding of the investment and payoff (or return on investment) of education. In fact, most of society understands little of the value proposition of major investments such as homes, cars, etc., and understands even less about education.

The future workforce is not going into materials science and engineering. There are rational reasons for these disappointing decisions. For example, what motivates or incentivizes youth to go into STEM careers? Do they see jobs available? Do they see a future for leadership of the type exerted by scientists and engineers in other organizations?

There are high-value, public-private partnerships that align incentives and interests via collaboration initiatives, but most today are regional/local, and a generalization has not been articulated. There appear to be relationships between economic levels, human development indices, and society attitudes toward technology/STEM. The media has a role in driving interest in STEM in youth. For example, the “CSI” (crime scene investigation) television show made forensic-based science courses attractive. The student today has a circle of influence that sends direct and subtle messages about the value or lack thereof in pursuing STEM. There are some collaboration activities with K-12 and the public intended to change the perception of science and engineering as a career field, but they are largely at the local level.

6. Trends and Observations

One of a number of important trends concerning teaching concepts is teaching materials concepts within the contexts of both types of learners—those that deal best with concrete examples and those that prefer the abstract. Among the examples of these programs within universities and technical societies is the ASM goal of developing high school courses that teach chemistry, physics, etc., through a materials science course. Reports, such as those from the NRC, document the benefit to learning. Children like “hands-on,” and youth need to see relevance, have fun, and work with natural curiosity. Critical skills should be taught early (K–12) and continued through university.

Another important trend is teaching concepts as a function of application to both engage undergraduates and prepare them for the job environment early. This includes interdisciplinary training, product development focus, applied learning, and relevance. There is also a trend toward teaching fundamentals using more relevant, modern, and exciting materials to more fully engage students.

The following observations resulted from the conference.

Today’s skills are different from the past:

- “Hunter-gatherer” – There is an effort to hunt for, accumulate, and build on knowledge. It is a slow process.
- “Filter-selector” – We are surrounded by nearly instantaneous information. It is necessary to sort out and select what is appropriate.

- An important role is critical thinking and developing the ability to exploit the results.
- “Vocational” and technical tracks can play a role in workforce development. For some, there is a perception that a hands-on focus on academic knowledge is as important as the ability to apply knowledge.
- There is tension between abstract and concrete thinking. However, the enterprise needs both so that both can address needs and adapt quickly. It is a challenge to meet both learning styles.
- Diversity is sought by many, including diverse expertise, generalist/specialists, cognitive skills, and industry needs.

The DOD has seen broad trends in the classification and recruitment of scientists and engineers:

- Swings from very specific policies to very broad policies.
- Eased entrance to the DOD workforce and mobility once within the DOD.
- Today, DOD can write individually tailored recruitments, which works well in general. However, there is a challenge in recruiting and retention in mid-career.
- There are cumbersome personnel processes within the DOD. It takes too long to make recruitment decisions. For example, the Army has a 120-day decision period.

The materials and processes profession is not a large job pool; it is too small to rely on statistical interactions and connections. It is necessary to form alliances and proactively engage workforce recruitment and development.

Industry focuses upon depth because it is a competitive advantage. Specialists are associated with the industry and the products of the industry.

Government is more oriented toward breadth and flexibility, especially in materials and processes, which is a small group. Therefore, it is very important to acquire a different type of personnel development.

7. Significant Questions/Challenges

A number of significant questions were raised during the conference, including the following:

- A balance of imagination, creativity, and critical thinking vs. specific knowledge is needed. But what is that balance?

- What is the balance between materials science depth and materials engineering depth? Can we have both? What is the right balance of a strong academic foundation vs. the ability to be broad? Both are needed.
- How do we push “real world” teaming, interdisciplinary, and discovery skills lower (earlier) into the educational process?
- How do early professionals better network?
- Does the DOD do a good enough job articulating the value of MS&E when recruiting? How about its role in STEM and workforce development?
- How do we push independent research and strong mentorship lower into the education process? Doing so would be very valuable, according to NRC reports and early professionals.
- How do we integrate and mutually reinforce K–12 and higher education strategies?

The following are some challenges raised during the conference that can also serve as recommendations:

- Do we understand enough to define the problem? We have data, reports, and various projections, but many variables such as generational differences and economic factors still must be understood.
- What can the DOD materials and processes community do to ensure future workforce availability and to address some of the major findings here?
 - Can we share better and replicate the best practices (ASM?).
 - Can we reach the complete pipeline of materials science and engineering—scientist, engineer, technical K-12?
 - Can we have a clearing house for opportunities that would provide a single source on the web that shows what’s going on and available, and markets DOD job/intern opportunities and research equipment to better spur collaboration? Can DOD partner with the technical societies to achieve some of this?
 - Are we as a country losing access to part of our talent and ability pool (e.g., because of security clearance)?

8. Conclusions

The conference resulted in a number of very important observations about the subject of workforce development, and defined them based on input from all participants. A number of very significant questions and challenges were defined that subsequently led to the generation of pertinent recommendations for the technical community to consider for further action.

The final objective of the conference was very definitely achieved: provide recommendations to both the government and industry concerning actions that should be considered to ensure that the future of the U.S. technical community continue to develop the necessary properly educated scientists and engineers.

Appendix A. Agenda

This appendix appears in its original form, without editorial change.

APPENDIX A

AGENDA

Day 1

- 1200 **CHECK-IN**
- 1300 – 1330 Welcome and Introduction: *Dr. Lew Slotter and Mr. Dana Granville*
- 1330 – 1430 Keynote: "Broad Issues of Science and Engineering Education for K-12 Through University"
Dr. Lyle Schwartz
- 1430 – 1445 **BREAK**
- 1445 – 1525 Making the Transition from Models to Products:
"Multi-scaled Modeling in Composite Materials - Atoms to Aircraft", *Prof R. Byron Pipes (Purdue)*
- 1525 – 1625 Academic Panel on Accreditation, Balance, Curricula for the 21st Century. *Prof Kelli Bowman (Purdue)*,
Prof Mark Tuttle (Univ. of Washington), *Asst Prof Brian Landi (RIT)*
- 1626 – 1700 Meeting STEM National Security Workforce Challenges for Materials Science and the Current Operating Environment, *Mr. Jim Brazell (Ventureramp, Inc.)*
- 1730 **RECEPTION**

Day 2

- 0800 – 0945 Academic Panel: Unique Collaborations in Academia, *Prof Jack Gillespie (UDEL/CCM)*,
Prof Anthony Vizzini (Western Michigan University), *Prof Julie Chen (UMASS-Lowell)* and *Ms. Sue Lauscher*
(Univ. of Akron), *Mr. Michael Bettersworth (Texas State Technical College)*
- 0945 – 1045 Academic Panel: Role & Activities in Community Colleges, *Dr. Jerrilee Mosier (Ivy Tech Community College)*,
Mr. Frank Cox and Ms. Mel Cossette (Edmonds Community College)
- 1045 – 1100 **BREAK**
- 1100 – 1200 Panel, Young Professional Perspectives, *Dr. Maureen Foley (NAVSEA)*, *Dr. Matthew Dickerson (AFRL)*,
Dr. Christopher Tabor (AFRL)
- 1200 – 1315 **LUNCH** Speaker, *Dr. Vince Russo*, CEO, Aerospace Technologies, "Leading a Multi-Generational
Science and Technology Workforce"
- 1315 – 1415 Panel: Industry Needs and Activities in Developing Workforce of the Future, *Dr. Bob Schairik (GE)*,
Dr. Brian Fitzgerald (Business Higher Education Foundation)
- 1415 – 1515 Panel: Technical Society Role in Workforce Development, *Mr. Charles Hayes (ASM)*,
Dr. Sandra DeVincent Wolf (MRS), *Dr. George Spanos (TMS)*
- 1515 – 1530 **BREAK**
- 1530 – 1730 Panel: DoD, NASA, & Gov Lab's Role and Activities, *Dr. Steve McKnight (NSF)*,
Dr. Mabel Jones Matthews (NASA HQ), *Dr. Tom Russell (AFOSR)*, *Dr. Michael Kassner (ONR)*,
Dr. Sandy Young (ARL)

Day 3

- 0800 – 0900 Policy Panel: How Does US Gov Better Engage Education, *Prof Annalisa Weigel (MIT)*,
Prof Ken Sandhage (Georgia Tech)
- 0900 – 1000 Policy Panel: DoD Adapting Existing Personnel Policy to New Needs, *Dr. Jocelyn Seng (IDA)*,
Dr. Lew Slotter (OSD)
- 1000 – 1020 **BREAK**
- 1020 – 1130 Impact of STEM Program for K-12 and Undergraduate Education, *Dr. Laura Adolfe (OSD)*,
Dr. Daniela Marghitu (Auburn University)
- 1130 – 1200 Development of Next Steps, *Mr. Dana Granville*
- 1200 – 1245 **LUNCH**
- 1300 Summary & Wrap-up

Appendix B. Conference Attendees

Dr. Laura Adolphe	U.S. Department of Defense Director of Defense Research and Engineering, Research Directorate
Ms. Diane Baker	SAF/AOR
Mr. Jim Brazell	IDEAS – An Innovative Studio
Dr. Keith Bowman	Purdue University
Mr. Michael Bettersworth	Texas State Technical College
Dr. Julie Chen	University of Massachusetts, Lowell
Dr. Tia BensonTolle	U.S. Air Force Research Laboratory
Dr. Julie Christodoulou	U.S. Navy Office of Naval Research
Dr. Dennis Chamot	National Materials Advisory Board
Ms. Mel Cossette	Edmonds Community College
Mr. Frank Cox	Edmonds Community College
Dr. Roger Crane	U.S. Navy Naval Surface Weapons Center-Carderock
Dr. Mathew Dickerson	U.S. Air Force Research Laboratory
Mrs. Stacia Edwards	Ohio Board of Regents
Dr. Barry Farmer	U.S. Air Force Research Laboratory
Dr. Gary Fischman	Future Strategy Solutions
Dr. Brian Fitzgerald	Business-Higher Education Forum
Dr. Ann Flynn	National School Boards Association
Dr. Maureen Foley	U.S. Navy Naval Surface Weapons Center-Carderock
Dr. Jack Gillespie	University of Delaware
Mr. Dana Granville	U.S. Army Research Laboratory
Dr. Donald Gubser	U.S. Navy Naval Research Laboratory
Dr William Hong	Institute for Defense Analysis
Mr. Chuck Hayes	ASM Material Education Foundation

Dr. Joycelyn Harrison	U.S. Air Force Office of Scientific Research
Dr. Christopher Hoppel	U.S. Army Research Laboratory
Mr. Warren Johnson	Universal Technology Corporation
Dr. Michael Kassner	U.S. Navy Office of Naval Research
Mr. Jay Kiser	U.S. Army Research, Development and Engineering Command
Dr. Brian Landi	Rochester Institute of Technology
M/G (Ret.) USAF Robert Latiff	RLattif Associates
Dr. Timothy Leong	U.S. Defense Threat Reduction Agency
Dr. Kenny Lipkowitz	U.S. Navy Office of Naval Research
Mrs. Sue Louscher	University of Akron
Mr. Mick Maher	U.S. Army Research Laboratory
Dr. Daniela Marghitu	Auburn University
Dr. Suveen Mathaudhu	U.S. Army Research Laboratory
Dr. Mabel Jones Matthews	National Aeronautics and Space Administration
Dr. Mickey McCabe	University of Dayton
Dr. Steve McKnight	National Science Foundation
Mrs. Neelam Mehta	U.S. Army Research Laboratory
Mr. Gene Mitchell	U.S. Navy Naval Sea Systems Command
Dr. Jerrilee Mosier	Ivy Tech Community College
Dr. Ignacio Perez	U.S. Navy Office of Naval Research
Dr. Byron Pipes	Purdue University
Dr. John Porter	University of California, Irvine
Ms. JaNassa Rainey	SAF/AOR
Dr. Tom Russell	U.S. Air Force Office of Scientific Research
Dr. Vince Russo	U.S. Air Force Research Laboratory (Retired)
Mr. Bob Rapson	U.S. Air Force Research Laboratory

Dr. Michael Rigdon	Institute for Defense Analysis
Dr. Ken Sandhage	Georgia Institute of Technology
Dr. Bob Schafrik	GE Aviation
Dr. Greg Schoeppner	U.S. Air Force Research Laboratory
Dr. Lyle Schwartz	University of Maryland
Dr. Lew Slotter	Office of the Secretary of Defense/Defense, Research and Engineering
Dr. George Spanos	Materials, Metals, and Materials Society
Dr. David Stepp	U.S. Army Research Office
Dr. Joycelyn Seng	Institute for Defense Analysis
Dr. Kathy Stevens	U.S. Air Force Research Laboratory
Dr. Erik Svedberg	National Academies
Dr. Chris Tabor	U.S. Air Force Research Laboratory
Dr. Mark Tuttle	University of Washington
Dr. Tony Vizzini	Western Michigan University
Dr. Annalisa Weigel	Massachusetts Institute of Technology
Dr. Sandra DeVincent	Wolf Materials Research Society
Dr. Sandra Young	U.S. Army Research Laboratory
Mrs. Cathy Santore	Zimmerman Associates, Inc.
Ms. Jeanne McDowell	Zimmerman Associates, Inc.

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